OTC
Owner Team Consultation

Smart Factories and the ‘New Normal’

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Introduction

It was only a short 12 months ago that things were vastly different. At the time, I wrote an article entitled *Beyond Capex: Future-proofing your IT investment for sustainable value delivery* (Halse, 2019). The article introduced smart manufacturing and covered the importance of getting the right digital philosophies established as early as possible during the conceptual stage of a capital project. It was too soon at the time to predict the full impact of the Covid-19 pandemic. Despite the ‘black-swan’ disruption, I believe that Covid-19 has accelerated the move towards digital business across the board, including a boost in so-called ‘smart manufacturing’.

2020 has also brought into sharp focus the volatile and fragile nature of the global supply chain. There is now the likelihood of a prolonged recession and even more disruption in 2021. But we should not lay the blame for all the recent disruption at the door of Covid-19. The global marketplace has always been an unpredictable place to do business. Before the events of 2020, many companies had embarked on a digitalisation programme to improve performance. The immediate impact of Covid-19 was to change the priority of many of these transformation projects. Some of these projects were fast-tracked while others were abandoned.

‘Social distancing’, a phrase few of us understood twelve months ago, has also required changes to accommodate remote working. In a typical factory or mine, while still maintaining some level of production the number of personnel quickly dropped to 40% of normal levels. The 60% are now working from home. Fortunately, cloud-based IT systems have allowed many companies to make the transition to a remote workforce relatively easily. The word ‘Zoom’ has now become a well-known verb. In many companies, there is no longer any intention to return to the large, expensive corporate office - working from home, despite some challenges, has proven effective, more flexible, and surprisingly efficient.

However, nothing is permanent, and the pandemic will pass. There is reason to believe that working from home might become the new normal and further drive a shift towards higher levels of factory automation.

Factors driving the adoption of smart manufacturing

Seven trends are driving the transition to smart manufacturing. These are:

- **Mass personalisation:** With the Internet and digital services pervading every walk of life, there has been a clear shift from mass manufacturing, towards personalisation (Devarajan, 2017). Driven by certain technologies, companies that previously mass produced products can now profitably make customised products and services aimed at individual customers.
- **The contingent workforce:** According to Baker (2020), ahead of Covid-19, 32% of organisations were in the process of replacing full-time employees with contingent workers (e.g. contractors) as a short-term cost-saving measure. After COVID-19, 48% of employees are now likely to work remotely (compared to 30% ahead of the pandemic). Many jobs will, as a result, shift from permanent to contract positions.
- **Connected manufacturing ecosystems:** A digital supply network is evolving out of the traditional linear 'design, source, make and deliver' supply chain. A digital supply network is a dynamic, interconnected system wherein the focus is on an optimised and holistic view of the entire supply chain (Mussomeli, Gish & Laaper, 2016). Driven by Industry 4.0, these interlinked networks were starting to form long before 2020, and this trend is accelerating as companies connect to shared services over the web. I will get back to this trend later in this article.
- **Evolving technological capabilities:** Previously expensive digital technologies have now matured to the point where they are now affordable and readily accessible. Examples include on-demand cloud services such as 'big data' storage, advanced analytics, and artificial intelligence (AI). At the same time, new hardware products such as augmented reality visors or glasses are becoming available. We have all become familiar with these concepts, ideas that back in 2000 few of us had heard of beside in science fiction. Where in the past, these technologies were only affordable by the larger companies, it is now entirely feasible for a small company to have access to these tools.
- **Complexity:** Partly because of the increased access to more data and the latest technological innovations there has been a vast increase in complexity, both within and outside the factory walls. Managing this complexity requires a systematic approach to the design of the architecture of digital systems. Early tactical IT projects that set out to 'prove a concept' have resulted in working technologies that are now part of the mainstream IT environment, requiring elevated levels of governance and management.
- **The volatility of supply and demand networks:** As the supply and demand networks become more connected, the impact of a disruption on any one part of the system can quickly ripple through the whole network. Identifying these disruptive events and taking appropriate precautionary measures is necessary to prevent the entire system from becoming unstable. A recent example is the impact

on the local brewing industry that resulted from a sudden banning of alcohol sales during lockdowns. This ban rippled back to production, inventory, suppliers of glass and packaging, warehousing, and logistics. The ripple effect even started to affect farmers supplying seasonal crops like malt grains and barley. Each of these elements of the supply chain work on different time scales, from hours, weeks and even seasons; making forecasting and planning exceedingly difficult.

- **Next-generation workforce:** As experienced people retire from manufacturing, a new generation of digitally literate people are entering the workplace, driving internal demand for advanced digital technologies within the enterprise. Many organisations are not ready for this and cannot satisfy the new requirement, yet.

Smart manufacturing is not an entirely new concept. It can be regarded as an evolution of traditional automation and control systems, in turn, accelerated by using new technology.

Several key technology enablers have made this possible. One is the ubiquitous connectivity of the Internet and open connectivity standards like TCP/IP being adopted in the factory. The proprietary industrial networks of the 1980s are steadily being replaced by ethernet infrastructure that theoretically allows addressable devices on the plant to connect to the Internet. Most modern plants are now covered by industrial grade wi-fi. This will, of course, introduce the need for better cybersecurity and more advanced update/deployment systems, but these systems too are evolving.

The resulting convergence of connectivity standards is also leading to organisational changes. In many factories, traditional IT reporting to the CIO has for some years been merging with OT (operations technology) which reports to the operations or engineering manager. These changes in reporting lines tend to break down historical silos and can accelerate innovation.

Smart manufacturing defined

Smart Manufacturing is a broad term used to define the complete digital manufacturing universe, including:

- The digital supply network.
- Product lifecycle management – from idea to manufactured product.
- The responsive factory.
- New manufacturing technologies such as additive manufacturing (3D Printing).
- The cloud.
- Widely adopted standards of communication and data.
- Big data.
- The industrial internet of things.

- Edge computing.
- Mobile devices.
- Artificial intelligence.
- And more…

A critical characteristic of the smart factory is its participation in the wider supply chain. Traditional supply chains are linear in nature, with a step-wise progression of design, plan, source, make, and deliver. Burke, Mussomeli, Laaper, Hartigan and Sniderman (2017) maintain that many supply chains are transforming from a linear sequence to a dynamic, interconnected system that can more readily incorporate partners and evolve to a more optimal state over time. They consider an interconnected, open system of supply operations as the foundation for how companies compete in the future. Burke et al (2017) refer to this new supply chain as the 'digital supply network', as shown in Figure 1.

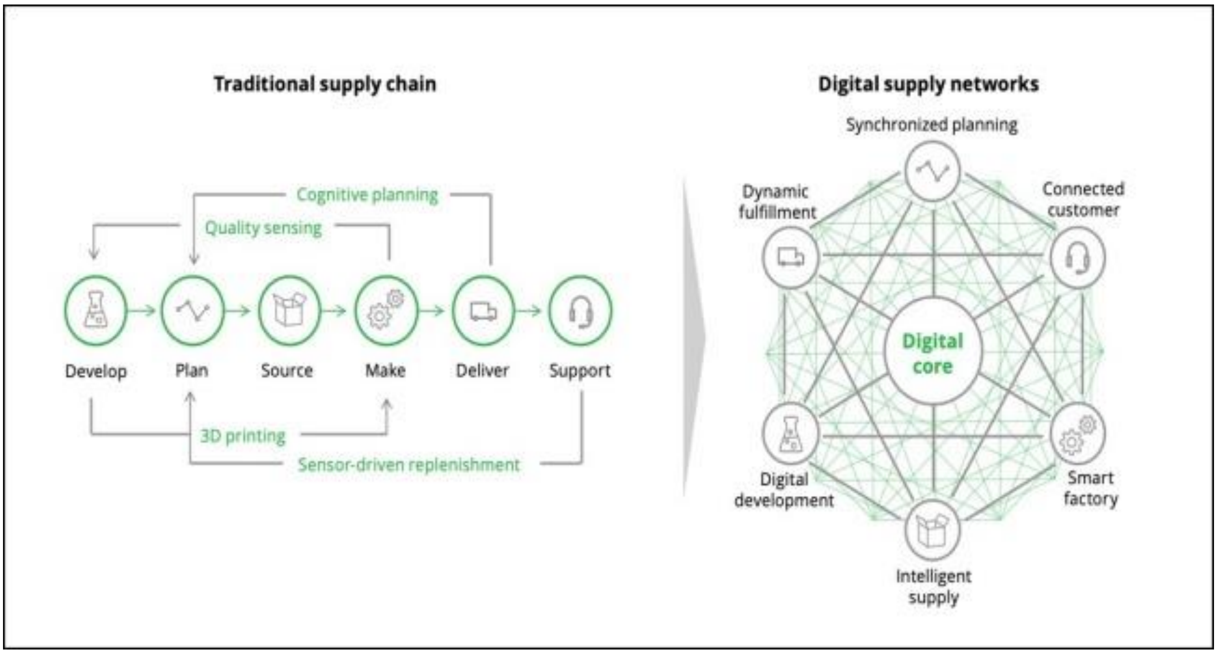

Figure 1: The transition from traditional linear supply chain to a digital supply network (Burke et al, 2017)

It might be useful to think of the digital supply network as having two parallel streams: One stream being the physical flows of materials from a supplier, through manufacturing, to the customer. The other is the parallel flow of the related digital information. Both streams hold value to the business, the one being tangible and the other being intangible. The digital information is increasingly now being referred to as the 'digital twin'.

Another way of thinking about smart manufacturing is to look at the way information is integrated across the business. In the past a point to point integration was used to connect (for example) level data from a sensor on a stock tank to the inventory module in SAP. But these old point integrations are not sufficient in the new smart factory. A completely new approach is required for integration, being:

- **Vertical integration:** Connected IT systems from plant sensors to mobile devices in the hands of users. No more 'plant network' separate from the 'business network'.
- **Horizontal integration:** Integrated operational and business systems, from the sensor to the board room, incorporating all the in-between business processes. No more 'operational systems' separate from 'business systems'.
- **Value-chain integration:** End-to-end process integration across the entire value chain, including the suppliers of raw materials to end customers, and all in between. No more planning and scheduling applications that work with internal production data only.

One size of 'smart' does not fit all

One of the reasons that much of the information about 'smart manufacturing' is seen as marketing hype is that people sometimes confuse 'manufacturing' with a single, homogenous concept. This is, of course, not true. 'This will never work here' does not mean that it cannot work somewhere else. The reality is that there are significant differences in manufacturing processes, methodologies and even cultures between vertical industry segments, such as mining, gas, energy, pharmaceuticals, and others. There are also substantial differences in the way the products are made, for example, between discrete, repetitive and process manufacturing.

I like to use four broad classifications describing manufacturing processes, namely:

- **Process manufacturing:** Characterised by process streams flowing at a steady state. Examples are an oil refinery, a metals refinery, or an ammonia plant. These processes don't/can't start-up or shut down quickly and generally make a product to stock. Specific industries like power generation have similar steady state characteristics, except that it is not possible to store the finished product. In process manufacturing, emerging smart factory technologies are used to improve the steady-state efficiency and to reduce costs.
- **Batch process manufacturing:** Characterised by recipes that make product variations. Each batch starts and stops at a specific time. For example, paint plants, breweries, PVC plants, and pharmaceutical plants. Multiple product codes (different grades and packaging variations) characterise these factories. Many of the emerging smart factory concepts are applicable here, for example, by efficiently reducing batch sizes, a factory can make a broader range of product variations.
- **Repetitive manufacturing:** Characterised by a complicated procedure that is repeated to make a product again and again. Examples are assembling bicycles or electronics devices in a production line. Entire product lines are planned and executed in response to demand from the market. There are many opportunities to

use smart technologies to meet personalised customer requirements.

- **Bespoke or custom:** Characterised by a product lifecycle approach that incorporates the customer specification, engineering/design, assembly, and the subsequent use of a one-off product. Examples are very high-value components such as specialised computer equipment, or once-off machinery. These processes are generally ‘make-to-order’. Here the smart factory concepts are focused to enhance the entire lifecycle, for example enhancing the close collaboration between design, manufacturing, and service teams.

In general, a factory will have many instances of these different manufacturing types. In an oil refinery, while the refinery itself is a process plant, there are still elements of batch and discrete in areas such as maintenance spares (bespoke), inbound/outbound logistics (repetitive), blending operations (batch), etc.

The old manufacturing model

The modern smart factory describes an overall integrated digital/physical system both within the factory boundaries, as well as outside across the entire value chain. However, most traditional models of manufacturing do not accommodate this holistic view as illustrated in the 2008 example by Manufacturing Enterprise Solutions Association (MESA, 2008) in Figure 2.

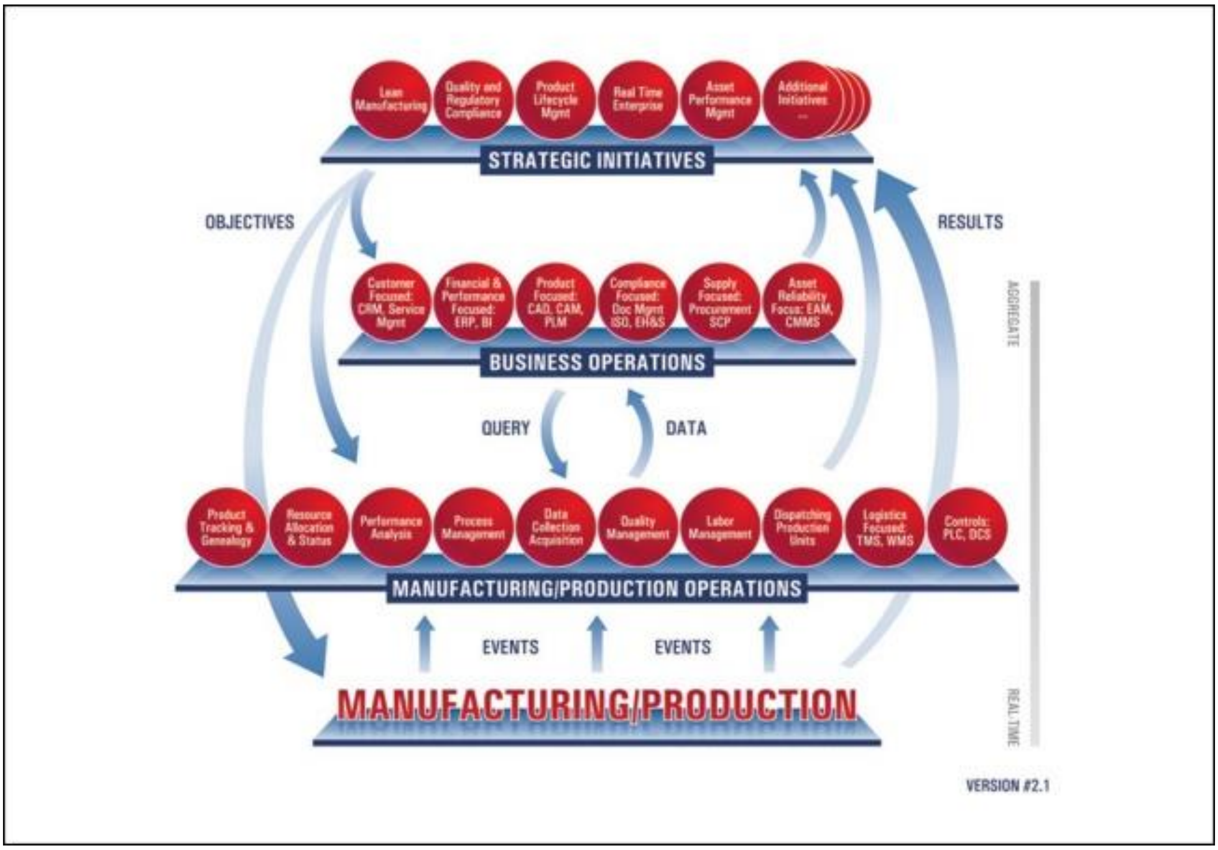

Figure 2: The MESA model of manufacturing (MESA, 2008)

This traditional model of manufacturing spans from enterprise-level strategic initiatives to business operations to plant operations and actual production. It also provides a conceptual illustration of how events in the plant operation feed and inform all other events, and how aggregate views from the enterprise can drill down through operations to the real-time production views (MESA, 2008).

To me, the model is fundamentally flawed because of its inward looking approach. The model does not adequately reflect the modern digital supply network, which I believe to be a major shortcoming. Many companies adopted this model in the way they have configured their manufacturing and business systems back in the early 2000's. Many business software providers like the big enterprise resource planning (ERP) vendors also took this inward looking approach. Unfortunately, the result has been to limit the way business serves its customers with overly complex inwardly focussed mega ERP systems, holding back change.

To MESA's credit, they are working on a new model of manufacturing that incorporates smart factory concepts and I for one look forward to seeing how this evolves. In time the sluggish world of ERP software might also catch up; that is an entirely different article for the future.

Examples of the use of smart technologies

In the following section, I explore some selected examples of smart technologies and how they are being applied in certain manufacturing scenarios. I discuss robotic automation, artificial intelligence, predictive maintenance, image recognition, warehouse automation, additive manufacturing, and augmented reality.

Robotic automation

Robots can reliably perform repetitive tasks like assembly, welding, shipping, packing, and materials handling. The smart factory will utilise robot technology to replace manual processes to improve the reliability and control of operations. Robotic automation can reduce costs, improve quality and throughput. Figure 3 shows an example of a vehicle assembly stage using automated robots.

One consequence of robotic automation is a shift from manual, labour intensive mundane jobs to newly created positions such as data analysts and systems specialists. This remains a challenge, but one that the motor manufacturers have seemingly overcome.

Figure 3: Automated robots used in a vehicle assembly application

Artificial Intelligence (AI)

There are many potential applications for AI in the smart factory. Machine learning can enable self-learning, predicting, prescribing, and optimising supply chain performance automatically across business functions. Digital supply chain models can handle more complexity, making them more dynamic, flexible, adaptive, and efficient, even more so than humans (Hajibashi, 2018).

Real-time data collected across the digital supply network can, in theory, feed into an AI model that can forecast supply and demand in a factory. An example AI modelling technique is the neural network. The more input data, the more accurate the neural network can predict outputs. While the theory is sound, in practice it is not that easy. There are many nuances to this approach that requires highly skilled development of the models. In some industries such as FMCG (fast-moving consumer goods), the potential business benefits of getting a neural network model to work well are significant enough to justify a research and development team of full-time data scientists. In other industries like quantifying the extent of underground geological resources, there are similar significant benefits of AI technology.

Predictive Maintenance

The use of smart sensors connected to the internet enables the remote monitoring of real-time equipment conditions from anywhere.

Predictive maintenance in the industrial setting has been in use since the 1990s. Vibration monitoring and analysis have been used extensively to monitor and protect expensive moving equipment like high-speed turbines. Since then, new, cheaper, even more, robust internet-enabled smart sensors have evolved. Companies can connect these to a cloud-based data store. OEM equipment vendors can now monitor their products as used in real-time to help predict failure. The manufacturer can offer this monitoring and preventative maintenance as part of the total service. Over time, all critical equipment in a smart factory might be serviced entirely by third parties under service level agreements using this approach.

Image Recognition

The use of industrial-grade digital cameras is becoming a typical application for quality control in manufacturing. High-resolution detection of defects is possible at a microscopic scale, such as in semiconductor manufacturing. For slightly larger items, cameras can detect faults at the micron scale far better and faster than the human eye. Companies can use spectral imaging, in combination with software pattern matching and image recognition, to identify quality defects with a higher level of precision and accuracy than conventional inspection techniques.

The smart factory of the future will likely make extensive use of imaging technologies to monitor processes for non-conformances or deviations, thereby reducing waste and improving quality management. Companies can also use digital imaging to monitor people's activities during potentially dangerous work to check that the correct protective equipment is worn and that the proper procedures are being followed.

Several companies are now performing surveys and inspections of large factories using cameras mounted in drones. The data from the drones can accurately determine the status of a building programme, something that quantity surveyors will appreciate.

Warehouse automation

Automated warehouses are already widely established and will definitely be a part of the future smart factory. The use of AI and machine learning technologies with intelligent sensors, robots, and advanced warehouse management software can all result in a highly automated warehousing system that can reduce labour costs by up to 70%.

The robots themselves can range from relatively simple guided vehicles to fully autonomous mobile robots capable of picking and replenishing stock items automatically. In some applications, warehouses can make use of aerial drones to pick from shelves too high to reach with normal forklifts. The value of the automated warehouse is increased service levels, improved safety, reduced costs, reduced errors, and reduced waste.

There are many examples of automated warehouses. One local example I have encountered is a textile company that has a fully automated warehouse to manage their safety clothing stock at their central warehouse in Gauteng. A combination of voice recognition and automated picking technologies cater to over 25 000 pick face locations. Individual customer orders can be processed, picked from stock, and personalised with branded logos and then be packed into individual cartons, all using an automated process.

Figure 4 shows a typical robot picker-arm as used in a fully automated warehouse system.

Figure 4: A robot arm used for packing shelves or picking from stock

Additive manufacturing

Additive manufacturing, sometimes referred to as 3D printing, is the process whereby materials are joined to make objects from 3D models, usually layer upon layer.

Additive manufacturing can have a significant impact during the design/prototype phase. 3D printing is affecting the way companies design products, reducing the time from prototype to final design. The digital models are conducive to remote collaborative work; prototypes can also be quickly 'printed' in other design locations.

Augmented reality

By combining information from a digital camera with a view of the process, it is possible to help guide the operator to perform a specific complex task. Augmentation is useful in situations where it is difficult to have the right skills available for all tasks in a factory environment. A remote expert, or even a programmed procedure, can be displayed to the operator in the right context.

Figure 5 shows an example of a mobile tablet being used to augment a warehouse image with real-time stock picking information.

Figure 5: An example of the use of augmented reality on a mobile device

Practical considerations when starting out

It should be apparent from the discussion so far that there is a great deal of potential in adopting these new technologies to create a smart factory. However, it should also be clear that there is no single solution that will apply in all situations. Each of the technologies discussed above has a particular application for which it is suited. Always use the right tool for the job.

The business case must always determine how a technology project is started. In the case of the smart factory, there are likely several smaller projects run as a programme, rather than one big project.

What is essential is to make 100% sure that what is implemented will still work far into the future. Change can be expensive, and any improvement initiative will require careful upfront planning. Seek expert advice where necessary by using experienced consultants. Be cautious of vendors that push their product as the silver bullet. Get an independent second opinion. A good starting point is to audit your existing information and communications technology (ICT) and process automation systems, together with the organisational structures supporting them. From this, it is easier to see the gaps and chart the way forward towards a desired future state.

The word ‘agile’ is sometimes used to help describe the cultural change needed in a smart manufacturing environment. Implementing many of the technological innovations described in this article will require a different approach to management (Denning, 2018). Established management practices may no longer be useful when companies have to move quickly to keep up with growing complexity. They soon find that their projects are getting held back. Agile management which grew out of the software industry offers some solutions. Agile involves smaller, independent self-organising teams with a narrow scope of projects and a primary focus on the customer.

Management style and the culture of an organisation must be ready for the new smart factory. From my own experience, not all companies are well prepared for this change.

Closing remarks

The smart factory is evolving and changing the way businesses will operate in the future. The changes are accelerating because of the global disruption in supply chains. Covid-19 is contributing to this and is acting as a catalyst. While there are many viable automation technologies available today, not all of them will apply to all manufacturing scenarios. Equally, it is unlikely that any plant or factory will be unaffected. Competitive forces will eventually force change.

Finally, the implications of smart manufacturing will run deep into the culture of the organisation, and any changes here will require exceptional leadership skills.

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